Can Wireless Preserve the E2E Argument ?

Dumb vs. Flow-Adaptive Link Layers (LL)

Low vs. High LL ARQ Persistency for TCP

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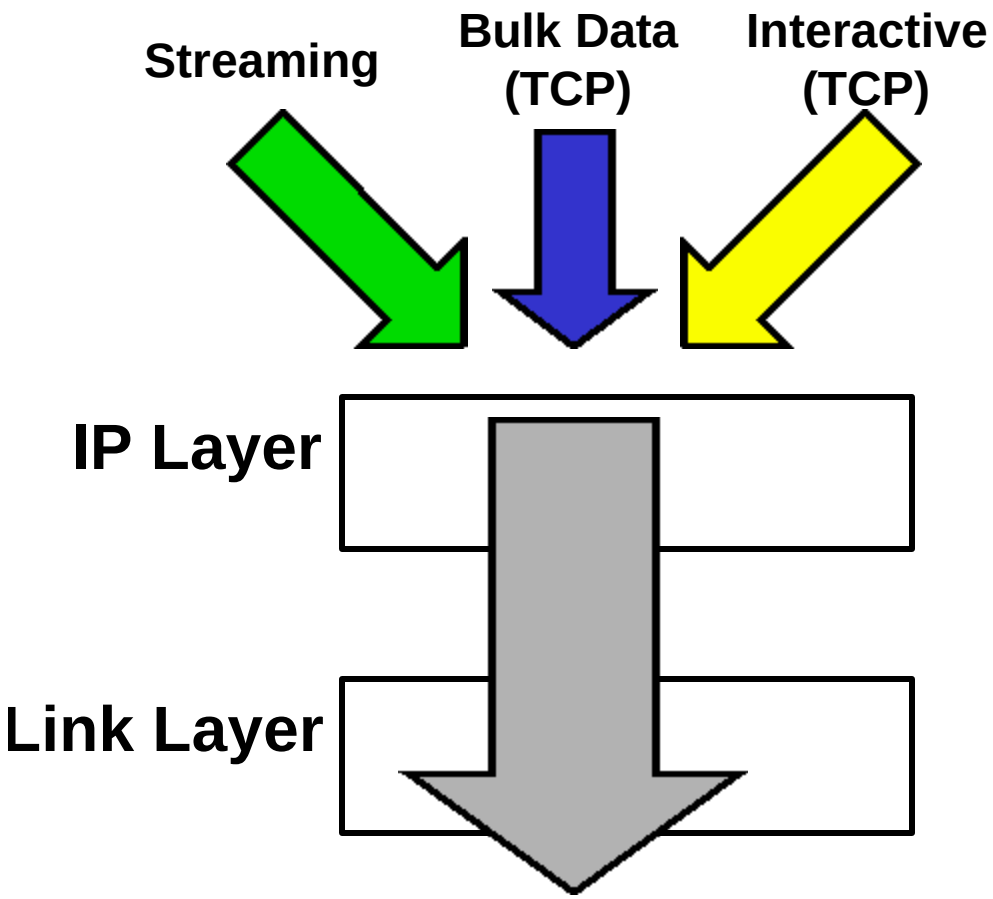
Link Layer Design Philosophies

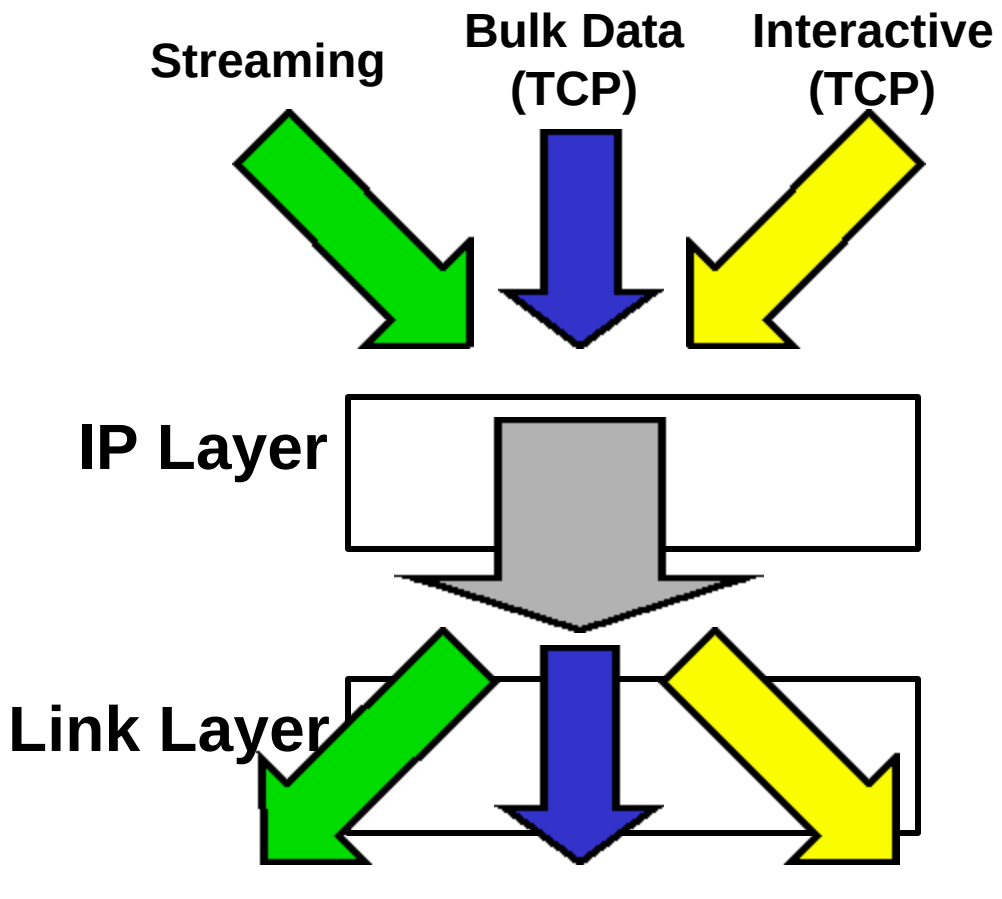
The "Dumb" Link Layer

(aka transport-blind, one-size-fits-all, …)



The "Flow-Adaptive" Link Layer

(aka transport-aware, …)



Wireless Link Layers SHOULD be Flow-Adaptive

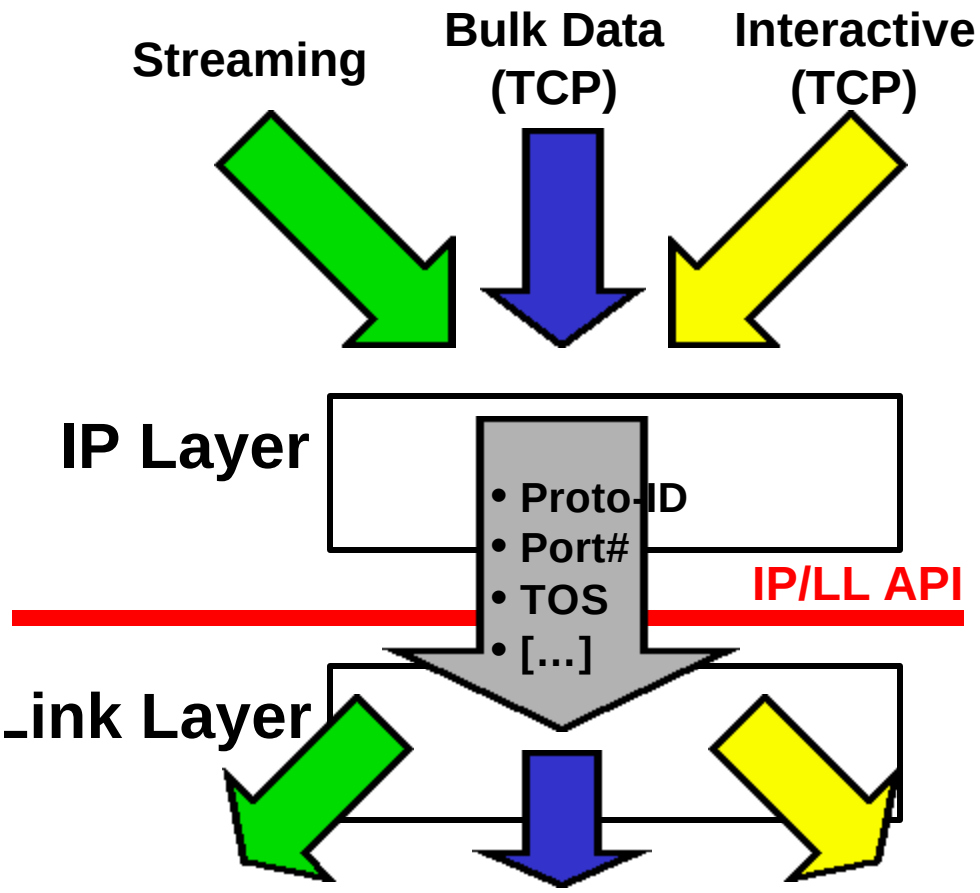
- **Flow-Adaptive Makes Little Sense for Wireline**
  - ⇒ **Because:**
    Wireline Link Layers have No Knobs for Tuning (not needed!)

- **Flow-Adaptive Makes Lots of Sense for Wireless**
  - ⇒ **Because:**
    Wireless Link Layers have Many Knobs for Tuning:
    FEC, Interleaving, ARQ, Power Control, …
  - ⇒ **Allows to Adapt Knobs to Flow's QoS Requirements**
  - ⇒ **Spectrum Efficiency**
  - ⇒ **Power (Battery) Efficiency**

How to Implement a Flow-Adaptive Link Layer

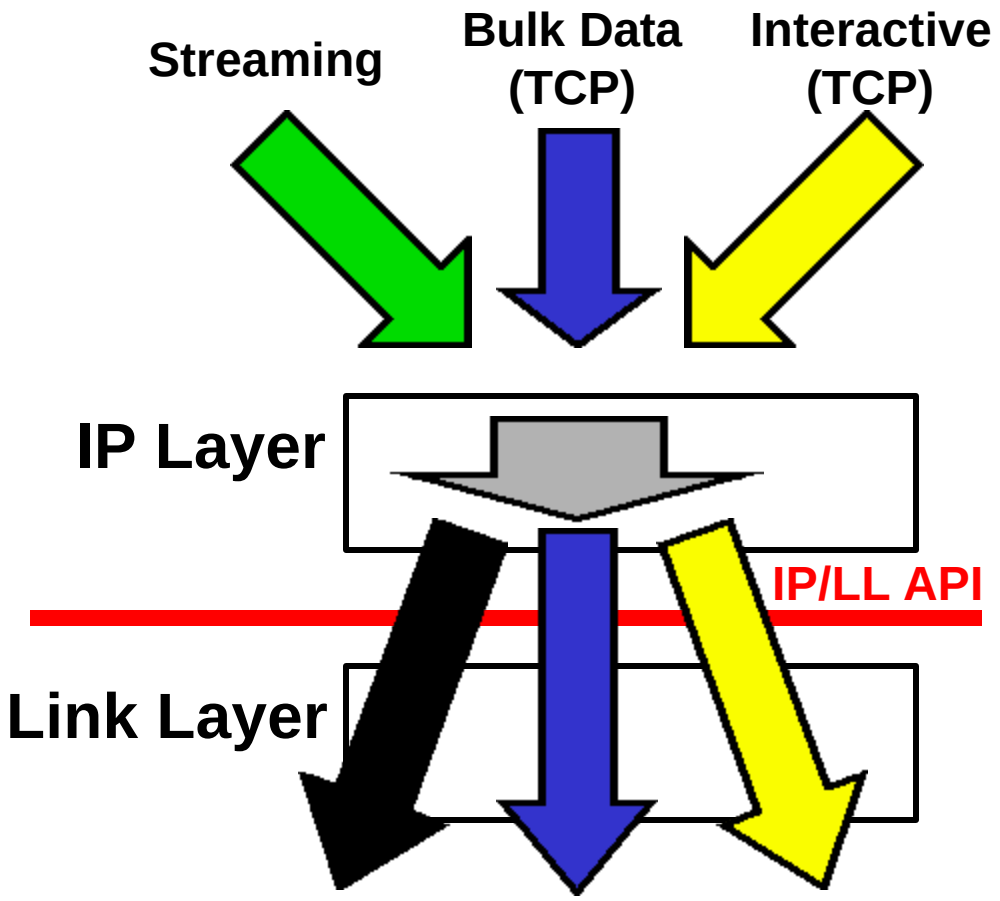
Link Layer Sniffing

(Not Maintaining Transport Layer State !!!)



Clean Layered Design

(a la E2E Argument)



BUT: E2E Argument Promotes Dumb LL …

- "<u>Everything</u> should h… …nd-points. The network inclu… …yers should remain dumb."

  ⇒ J. H. Saltzer, D. P. Reed, D. D. Clark, "End-To-End Arguments in System Design", ACM Transactions on Computer Systems, Vol. 2, No. 4, November 1984.

- E2E Argument:

  "[Link layer error control is] an incomplete version of the function provided by the communication system [that] may be useful as a performance enhancement".

BUT: LL Sniffing is Layer Violation …

True! On the other hand …

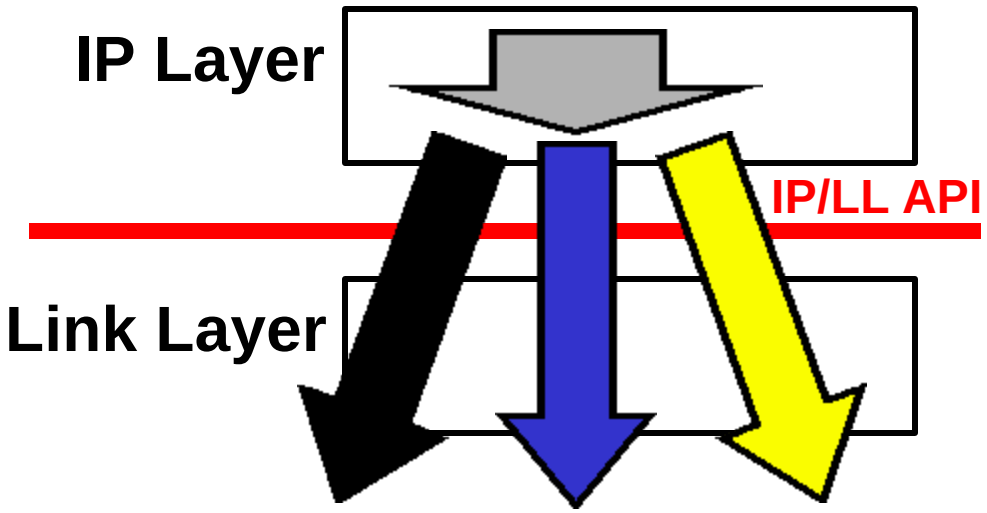
1. Trade-off: Pragmatism/Performance vs. “Beauty of Design”

⇒ **If LL Sniffing (Layer Violation) was such a Concern:**

“Call the Layer-Police to Put the ROHCers into Jail” :-)

2. We have an alternative:

⇒ **Extended IP/LL API**
New PILC Work Item?



BUT: Flow-Adaptive Breaks with IPsec …

Partly True …

1. **People that are so Paranoid to use IPsec Gladly Trade Performance for Security.**

   ⇒ **People who are less Paranoid Should Use TLS.**

2. **DS-field is unencrypted**

3. **IPsec-friendly Solution Possible (unencrypted TOS IP-Option?)**

Link Layer ARQ Persistency for Reliable Flows (TCP)

- **Assume Flow-Adaptive LL, i.e, TCP flows are separated**

- **Assume LL ARQ is Possible**

  ⇒ **Not the case on uni-directional links (e.g., some satellite links)**

- **LL ARQ Persistency for TCP?**

- **<u>Definition of "LL ARQ Persistency":</u>**

  The Time (in milliseconds) the LL Delays a Single IP Packet in an Attempt to Successfully Transmit it Across the Link.

BUT: We do Not Need LL ARQ …

- **“Simply set the MTU [illegible] and use TCP-SACK”**

  - ⇒ **Optimal Frame Size on some Wireless Links is less than 100 bytes (e.g., GSM, IS95, GPRS, UMTS)**
  - ⇒ **IPv6’s Minimum MTU is 1280 Bytes !**
  - ⇒ **Might Work for Satellite Links: Optimal Frame Size >> 1280 Bytes**

Use Highly Persistent LL ARQ for TCP

- **More Precisely, LL ARQ SHOULD try for up to 64 seconds (TCP's MAX-RTO) to Transmit a TCP Packet !**

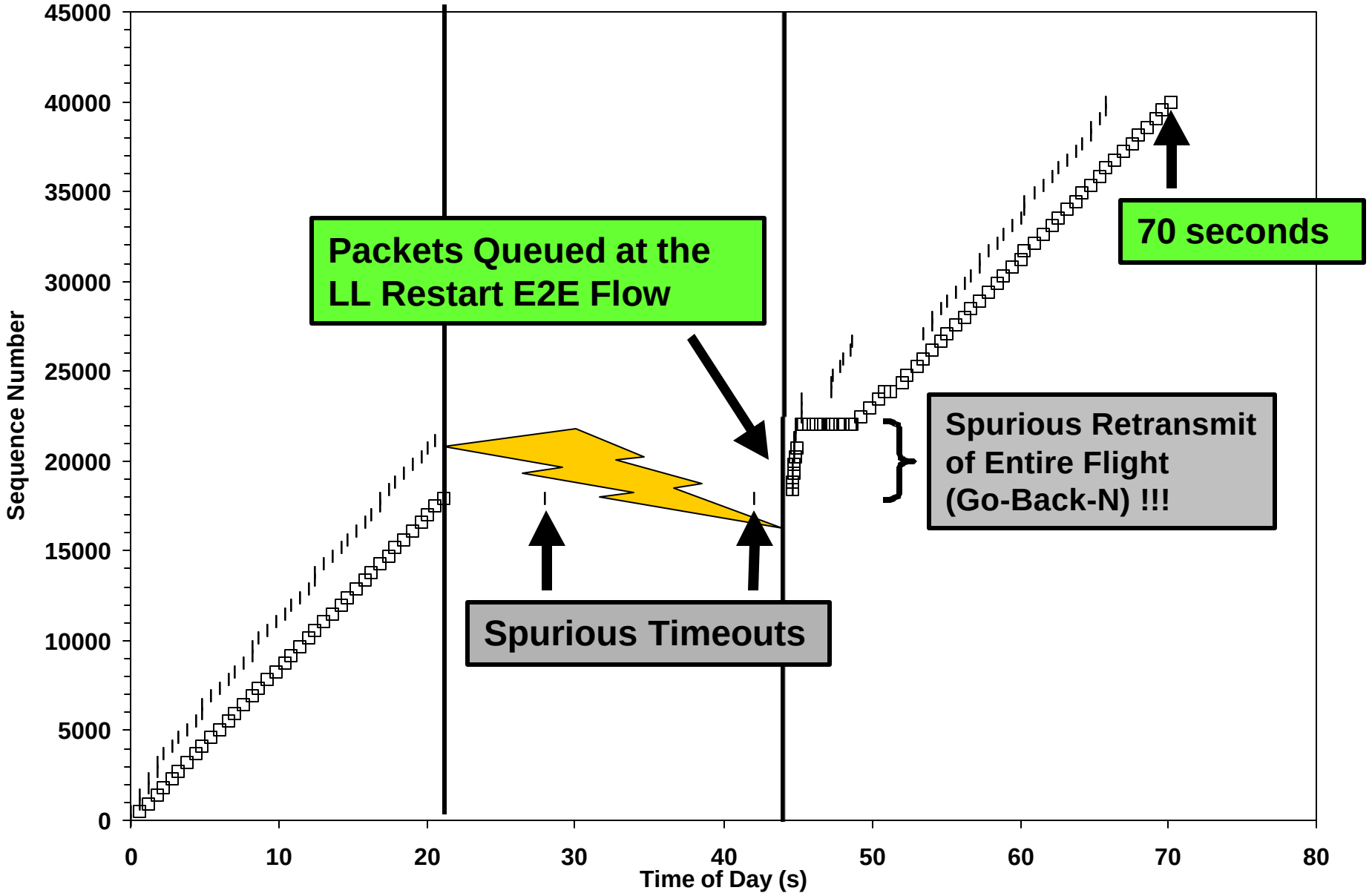
- **This is NOT Saying: Unbounded Queues!**
  - ⇒ **Queues Need to Remain Small (Active Queue Management)**
  - ⇒ **If Queue Beyond Threshold Þ "Drop From Front"**
  - ⇒ **Early Congestion Signal**

- **This is NOT Saying: Hop-By-Hop Instead of E2E Reliability!**
  - ⇒ **E2E Argument:**
    "[Link layer error control is] an incomplete version of the function provided by the communication system [that] may be useful as a performance enhancement".

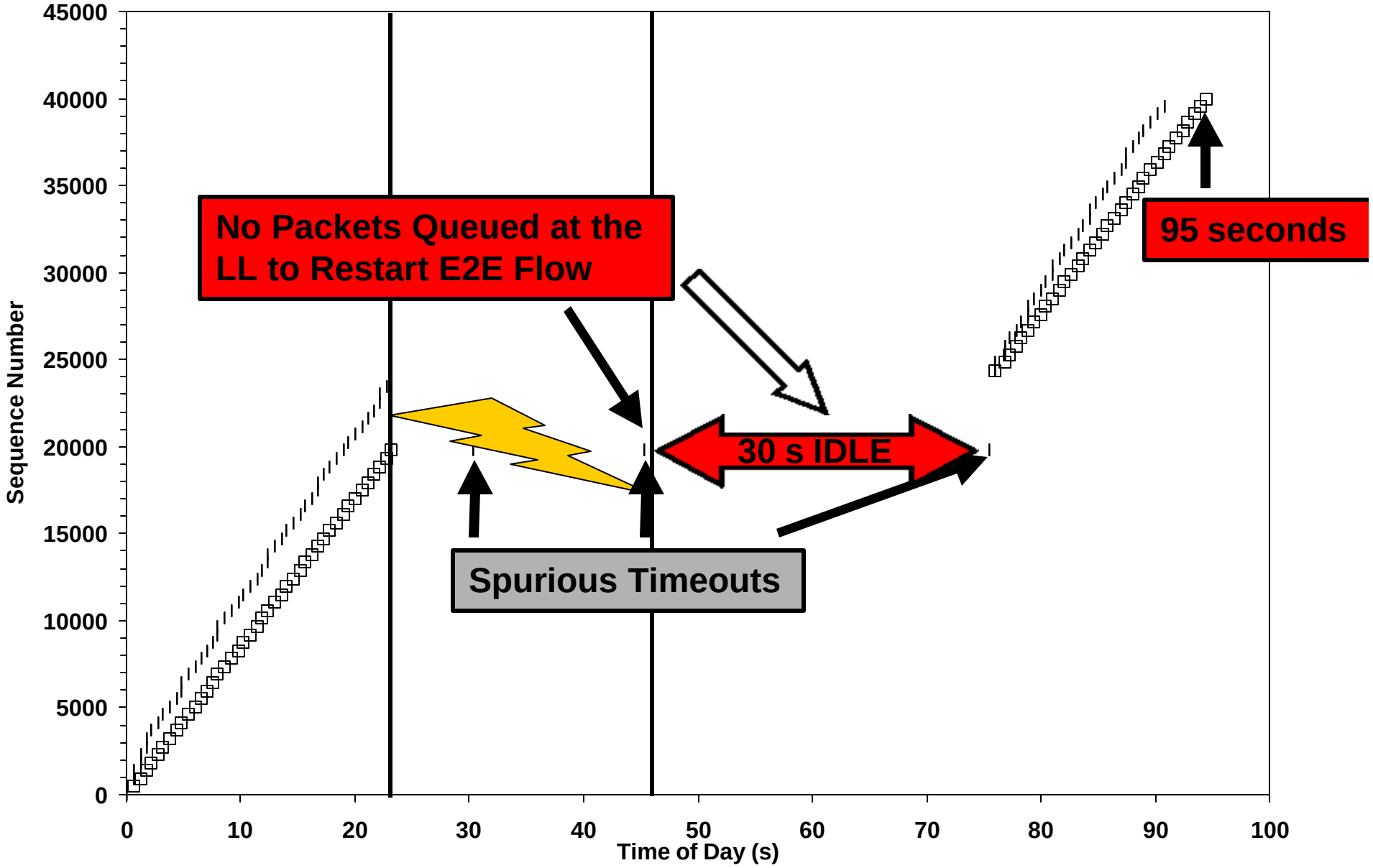
Why Such a High LL ARQ Persistency?

- **First of all, High Delays Due to LL ARQ are Rare**
  - ⇒ **Typically < 1 second (excluding transmission delay)**
  - ⇒ **Mainly Occurs During Transient Link Outages**
- **Most Spectrum & Energy (Battery) Efficient**
  - ⇒ **If the LL Can't Do it, TCP can't Do it!**
  - ⇒ **Discarding a Packet that Already Made it 90% Across the Link Makes No Sense!**
  - ⇒ **Measurements over GSM with LL ARQ Disabled and an MTU of 1500 Bytes Show up to 18% Undelivered Packets (Discarded by PPP due to CRC Error)**
  - ⇒ **RFC2914: "Congestion Collapse Due to Undelivered Packets"**
- **Robustness Against Link Outages**
  - ⇒ **No Need for an "ICMP-Link-Outage Agent" at the Basestation**

Link Outage & High LL ARQ Persistency



Link Outage & Low LL ARQ Persistency



BUT: Spurious Timeouts …

True, they Force TCP into Go-Back-N . On the other hand …

1. **Likely to be Solved in TSV WG**

   ⇒ **Eifel Algorithm**

2. **Go-Back-N Often Less Harmful than Waiting for Long RTO**

   ⇒ **See Last 2 Slides**

BUT: Inflated RTO …

True! On the other hand …

1. **RTO Decays Quickly after an RTT Spike; especially when Timing Every Packet (Timestamp Option).**

2. **If the Path's RTT Varies Largely, RTO should be Inflated, i.e., should be conservative.**

BUT: Head of Line Blocking …

Not True, as long as …

… we Allow the LL to Perform Out-Of-Order Delivery Between Flows.

- ⇒ **Requires LL Per-Flow Operations (Not Per-Flow State!)**
- ⇒ **However, No Scaling Concern on Last/First-Hop Links!**

A Word on TCP Proxies

- **TCP-Throughput =** $\frac{1}{RTT} \times \frac{1}{\sqrt{p}} \times C$

- **Flow-Adaptive LL + Highly Persistent LL ARQ for TCP**
  - ⇒ **Eliminates Non-Congestion Packet Losses on Wireless Link**
  - ⇒ **No Need for a Proxy to Avoid Influence on *p***
  - ⇒ **For High Latency Links, a Proxy Might be Needed to Avoid Influence on *RTT***

A Word on Robust TCP/IP Header Compression

- **Flow-Adaptive LL + Highly Persistent LL ARQ for TCP**
  - ⇒ **Eliminates Non-Congestion Packet Losses on Wireless Link**
  - ⇒ **No Losses Between Compressor & Decompressor**
  - ⇒ **No Need for Robustness in TCP/IP Header Compression Scheme !**
  - ⇒ **Only Things Left to do for ROHC WG: Compression of SYNs, FINs & TCP Option Fields (Timestamp, SACK, …)**

The Message

1. Wireless Link Layers SHOULD be Flow-Adaptive

2. Highly Persistent LL ARQ for TCP (all fully-reliable flows)

3. If 1. not feasible, e.g., due to IPsec, Low Persistent LL ARQ (< 100 ms ?) SHOULD be Operated for All Flows

Conclusion

Can Wireless Preserve the E2E Argument ?

YES!

The E2E Argument is (Still) THE Guideline

Leading to Well Designed Wireless Link Layers